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Magnetic Properties of Stressed LCMO Thin Films

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Beamline(s): U4B

Introduction: Doped $LaMnO_3$ exhibits colossal magnetoresistance (CMR), making it an attractive material for potential application as a next generation magnetosensor[1]. This material also exhibits interesting magnetic, structural, and electronic properties. These properties make it the focus of current research, with the goal of understanding the interesting magnetotransport properties[1-4].

The basic system, undoped $LaMnO_3$, is an insulator and becomes an antiferromagnet at low temperatures. By substituting Ca for La in the lattice, the ratio of Mn^{4+} to Mn^{3+} can be controlled. Controlling the Mn formal charge modifies the material properties in interesting ways. $La_{1-x}Ca_xMnO_3$ becomes a ferromagnet at low temperatures for compositions (x) in the range between 0.1 and 0.5, and undergoes an insulator to metallic transition at the Curie temperature. Well defined structural changes are coupled with these magnetic and electronic transitions. The structural change has been identified as a tilting of the MnO_6 octahedra of the distorted perovskite lattice[5]. The coupling of the magnetic and structural properties is also evident by the change in the lattice constants due to an external applied field[5].

This coupling of the structural and magnetic properties has led to the idea that by controlling the structural parameters, the magnetotransport properties may also be controlled. Control of the structural properties can be achieved through epitaxial growth on lattice mismatched materials, which can introduce either a compressive or tensile stress in the material.

Results: The soft X-ray magnetic circular dichroism capabilities of the U4B beamline at NSLS are ideal for investigating the magnetic properties of thin film systems. In particular, XMCD allows the quantitative determination of element specific magnetic moments[6,7]. We are currently investigating the magnetic properties of stressed $La_{2/3}Ca_{1/3}MnO_3$ films grown on $SrTiO_3$. Growth on STO introduces an in plane tensile stress in the LCMO overlayer. LCMO films less than approximately 35 nm thick grow expitaxially without defects to alleviate the structural stress, while films greater than this thickness break up into antiphase domains[8]. Figure 1 shows the experimental results for LCMO films of two different thicknesses grown on STO. Panel a shows the results for a 150 nm film. The top graph shows the absorption spectra at the Mn L edge at several different temperatures, both cooled in a magnetic field (FC) and in zero field. The spectra show little difference, indicating similar electronic structure at all conditions. The XMCD spectra shown in the lower graph, however, reveal that the magnetic moment at the Mn positions is several times smaller when the sample is cooled in a magnetic field. Panel b shows the results for a 30 nm film. The top graph reveals significant differences between the absorption spectrum at room temperature and those taken below the Curie temperature. This indicates that either an electronic or structural change is occurring simultaneously with the paramagnetic to ferromagnetic transition. The magnetic behavior of this film, revealed by the XMCD spectra in the lower panel, show very different behavior when cooling is done in the presence of an external field. Under field cooled conditions the film exhibits a net magnetic moment, while there is no net magnetic moment for zero field cooled conditions. These results illustrate the effect that the film structure has on the magnetic properties of LCMO. Further studies will investigate the role that differing composition, structural stress (via film thickness), and external magnetic conditions have on the magnetic properties of LCMO films.

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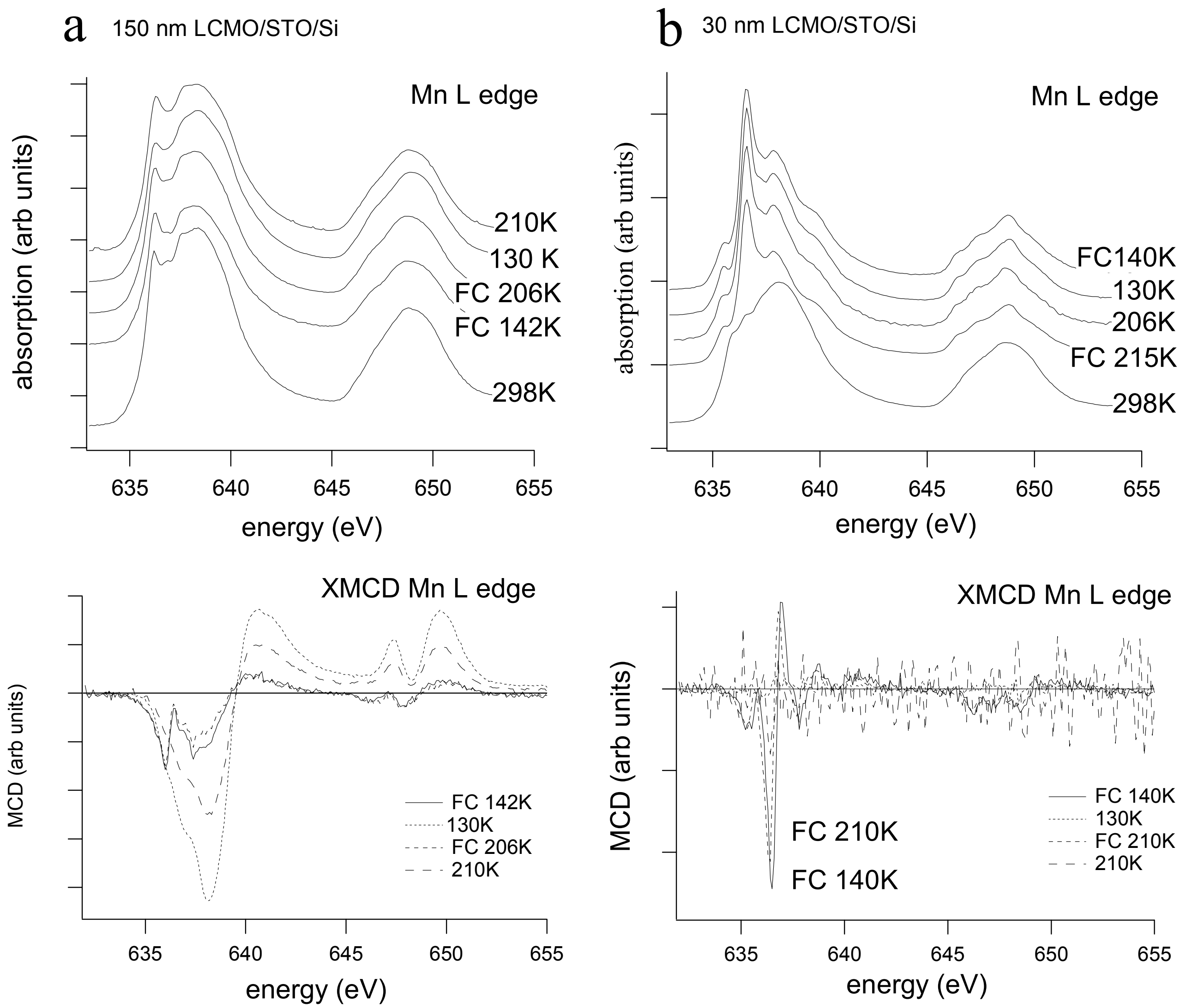

Figure 1: XAS and XMCD spectra of stressed LCMO thin films